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The Genetic Engineering of Food and the Failure of Science – Part 2: Academic Capitalism and the Loss of Scientific Integrity

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Abstract. Factors in the failure of the scientific community to properly oversee agricultural transgenics are presented. The large-scale restructuring of university science programs in the past 25 years from a model based on non-proprietary science for the 'public good' to the 'academic capitalism' model based on the 'knowledge economy' is discussed in the context of the failure of the science community to oversee the transition of transgenic crop technology from the research stage to commercialization. Discussed are increasing science community and university dependence on private industry funding and on development of proprietary technologies; monopolization of the make-up of expert scientific bodies on transgenics by pro-industry scientists with vested interests in transgenics; deficient scientific protocols, bias, and possible fraud in industry-sponsored and industry-conducted research; increasing politically and commercially driven manipulation of science within federal regulatory bodies such as the FDA; and bias in the peer-review process, tolerance by the scientific community of biotechnology industry manipulation of the information environment, and of biased treatment and harassment of non-compliant scientists. Discussed are future food production strategies for developing countries, recently framed in the 2008 UN-sponsored International Assessment of Agricultural Knowledge, Science, and Technology, an action plan that emphasizes non-proprietary, agroecology-based approaches to food production and does not include crop transgenics as a central strategy. The under-funding of non-proprietary agroecological approaches to food production is discussed.

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Factors in the Failure of Science

The hasty transition of the radical technology of crop transgenics from the research and development stage to commercialization, in which products of the young industry have permeated global food, feed, and fiber markets, has resulted in what may turn out to be the largest diet experiment in history. The lack of oversight that has led to this situation has been a major failure of science leadership. Part 1 of this paper reviewed the development and current picture of the transgenic crops industry, the history of oversight failures, from allowing biotechnology industry domination of US federal regulatory bodies overseeing transgenic products, to a lack of response to 'red flag' incidents and profoundly troublesome research findings on transgenic crops and foods, to the failure to adequately analyze and characterize the genetic and proteomic integrity of transgenic products.

At the core of this failure appears to be the restructuring of research university science programs in the past 25 years from a non-proprietary 'public goods' approach to one based on dependence on private industry. Additional ramifications of this shift that have been factors in the transgenics issue are:

- tolerance by the scientific community of bias against and mistreatment of non-compliant scientists whose work results in negative findings for transgenics, including editorial decisions by peer-reviewed journals, as well as tolerance of biotechnology industry manipulation of the information environment;
- monopolization of the make-up of expert scientific bodies on transgenics by pro-industry scientists with vested interests in transgenics;
- deficient scientific protocols, bias, and possible fraud in industry-sponsored and industry-conducted safety testing of transgenic foods; and
- increasing politically and commercially driven manipulation of science within federal regulatory bodies such as the FDA.

The Shift to Academic Capitalism and the Knowledge Economy

The large-scale shift of university science program funding in recent years from public (state and federal) monies to dependence on private industry sources has been described in a number of publications (Press and Washburn, 2000; Kleinman, 2003; Krimsky, 2003; Etzkowitz, 2005; Welsh and Glenna, 2007). The term 'academic capitalism' (Slaughter and Rhoades, 2004) has been used to describe the new orientation, whose cornerstone, as described by Slaughter and Leslie (1997), is science 'embedded in commercial possibility'. In this model, university research is harnessed to promote the emergence of the 'knowledge economy' in which 'new circuits of knowledge' linking university scientists with the 'new economy' are forged.

The academic capitalism model replaces or subsumes the model of the university described during the 1940s and 1950s by Vannevar Bush and Robert Merton. The 'public good' model as set out by Vannevar Bush (1945) maintained that university researchers must focus on basic science, must have the freedom to pursue scientific research wherever it leads, whether potentially profitable or not, and that there is to be a separation of the university and the private sector (Welsh and Glenna, 2007).

The CUDOS model of Robert Merton (communalism, universality, disinterestedness, and organized skepticism) (Schuster, 1995), otherwise known as the Mertonian norms of science, have traditionally been pillars of university science. CUDOS posited that scientific findings are common property, that scientists must remain detached from their research, and that the results must always be subject to healthy skepticism. In the Mertonian model there was little room for commercialism. The process and ramifications of the sea change from the Bush/Merton model of public good and communal science to the 'new economy' model underlain by private intellectual property has been extensively discussed in the work of Henry Etzkowitz (2005).

Central to the shift of universities to the new economy model has been the 1980 Bayh-Dole Act of the US Congress, which created closer ties between university research programs and private industry by increasing the ability of universities to retain intellectual property created with federal funding. One author offers no less than 18 citations attesting to the fact that the Bayh-Dole Act was 'extremely important' in the creation of this new university dynamic (Metlay, 2006). Biotechnology has been the sector benefiting the most from the post-Bayh-Dole arrangement (Argyres and Liebeskind, 1998).

Busch et al. (1991) write that the distinction between universities conferring benefits to private interests vs. benefits to the public good is sometimes blurred. These authors find that university administrators of technology-transfer offices, charged with securing funding opportunities from private industry and with promoting university–industry relations, see themselves as contributing to the public good by justifying their budgets to state governments. Smith-Doerr (2005) posits that the academic capitalism model does not replace or delegitimize the Bush/Merton model, as is common in other scientific revolutions, but coexists with it. Welsh and Glenna (2007) maintain that the non-profit nature of universities charges them with different roles and responsibilities in society than private enterprise and that these responsibilities entail service to the public good via non-proprietary research.

Shortly after the implementation of the Bayh-Dole Act, US science as a body predicted its own failure with respect to universities' handling of biotechnology industry money and ties. A 1984 American Association for the Advancement of Science report (the Nelkin Report) on the ramifications of the closer university–industry ties resulting from the Bayh-Dole Act, wrote:

> If ties to industry encourage secrecy, divert faculty away from university-centered research and education, bring external control of the direction of research, and allow profit motives to enter discussions about hiring or promotion, then such ties may indeed erode what is left of the image of the university as a detached institution able to provide relatively impartial, independent, and therefore credible expertise (Nelkin, 1984).

Derek Bok, former president of Harvard University, warned of the insidiousness of the slide toward loss of scientific integrity that comes with increased commercial ties: '[a]t the outset, profits to be made seem all too tangible, while the risks appear to be manageable and slight.… The problems come so gradually and silently that their link to commercialization may not even be perceived (Bok, 2003). He suggests pondering the lesson of the gradual commercialization of university athletics. Bok attributes the commercialization of academia to a loss of academic values and direction, in addition to the loss of state and federal appropriations and the shift to the knowledge-based economy.

Biotechnology industry influence over university research priorities can be seen at the 10-campus University of California system. Despite the tens of millions of dollars coming in to the university for research on transgenics, research on issues such as transgenic food safety, gene migration, and on ownership of the food chain are 'very small' (Norman Ellstrand, personal communication, 2007) or 'lacking' (Paul Gepts, personal communication, 2007) according to knowledgeable faculty. This imbalance is reflected at the USDA, which disburses research funding to universities. In the period from 1992 to 2002, the USDA disbursed $1.8 billion for biotechnology research. Approximately 1% ($18 million) of this went to risk-related research (Mellon and Rissler, 2003). Biotechnology industry influence and involvement at the University of California is growing. Recently there has been controversy over the University of California Berkeley's proposed acceptance of $500 million from BP Corporation, mostly for biotechnology research (Brenneman, 2006).

Welsh and Glenna (2007) present evidence that investments in crop biotechnology research have 'overwhelmingly been targeted at plants and traits that are of interest to the largest firms'. The authors present the case that research on non-proprietary solutions which benefit the wider public has been lacking and that this arena should be central to the mission of universities and other non-profit research institutions, and that 'an increasing number of authors argue that the mission of universities to address public concerns has been altered'.

How have science faculty dealt with the change to profit-oriented science? Smith-Doerr posits that an important factor in university scientist legitimization of more commercially oriented biotechnology research is the shift to a network form of organization connecting scientists in university and industry, as distinct from the more traditional dual hierarchical structure. This network dynamic blurs the boundaries between the two environments; whereas in the hierarchical model the boundaries between university and industry are clearly defined and the two are segregated. Ambivalence and uncertainty are more easily dealt with by players in the networked model, according to Smith-Doerr (2005).

Given the increasing dependence on industry funding and proprietary science, scientists who have invested their careers in genetic engineering and who have second thoughts about continuing may not easily be able to change to another field. Says one veteran transgenics researcher: 'As a scientist, once you narrow down into GE, your skills are very much in that area. You can't just say, "I don't like this area any more, I'll zip over to plant breeding instead"' (*Press*, 2007). Nor can scientists easily carry out research or raise questions that put transgenics in a negative light. Such research appears to be lacking at US universities. This may also be because as more pro-industry scientists populate science faculties, they exert a pull on neutral faculty towards industry-oriented research (Stuart and Ding, 2006).

The New York Times, in a 2009 article 'Crop scientists say biotechnology seed companies are thwarting research' (Pollact, 2009) reported that 26 crop scientists submitted a statement to the US Environmental Protection Agency protesting the agreements they are required to sign in order to acquire transgenic seed, which limit their ability to do needed research on transgenic crops. The result, they write, is that 'no truly independent research can be legally conducted on many critical questions regarding the technology'. The scientists requested that their names not be used as they feared repercussions that would affect their careers.

It is to the bewilderment of this author that, despite the august tradition of academic tenure and its protection, so few US scientists have taken on research that examines the glaring questions which have clearly and persistently arisen on issues of food safety and environmental and genetic integrity in crop and food transgenics – questions that have persisted for some 15–20 years. If ever there was a *raison d'être* for the tradition of academic tenure, it is to protect scientists who carry out such unpopular 'against the tide' academic work. Needed are sociological studies which go beyond examining the broad process of scientists shifting to the 'knowledge economy' and which examine how scientists have dealt with the ample evidence of profound problems with transgenics. Were most scientists insulated from exposure to such evidence? Or, if exposed to evidence of problems in transgenics, how did scientists make decisions to remain silent and go with status quo vs. becoming a transgenics promoter vs. raising unpopular questions?

One issue that I, the author, have had to deal with in writing this paper is that its publication and subsequent appearance on my resume will likely take me out of the running for academic and teaching positions at the majority of agriculture programs (my area of training) in the US, even those that prominently feature sustainable and organic programs. There has clearly been an unwillingness in agriculture-related programs to openly debate the issue of transgenics. It is generally undergraduate groups, who have much less at stake, who bring the transgenics debate to universities. A number of faculty whom I have approached to give my talk on this issue, assuring them that it is well-researched and not an 'anti-technology' rant, have simply told me that it is too risky for them to sponsor, the issue is too controversial or unwanted. Undergraduate groups have been much more receptive.

Bias against and Mistreatment of Dissenting Scientists

The issue of suppression of dissent in science has reared its head in the transgenics issue. Sociologist Brian Martin, in a paper 'Suppression of dissent in science', writes on the title topic: 'there is no body of work in sociology on the topic and no standard theoretical frameworks for dealing with it' (Martin, 1999).

Bias against dissenting scientists in transgenics has occurred in hiring and promotion decisions, illustrated by the Chapela and Pusztai affairs. In the former, University of California scientist Ignacio Chapela, whose research showed transgene contamination of native corn in Mexico (reviewed below), was denied tenure by a committee which, according to one science historian, was characterized by 'conflict of interest as naked as it gets' (Abate, 2003). (Chapela appealed and was later granted tenure.)

The Pusztai Affair

Arpad Pusztai of the Rowett Institute was one of the top plant transgenics scientists in Europe. His team was selected to develop safety-testing protocols for genetically engineered foods, and he developed a project to insert genes for a lectin, a natural insecticide, into potato. Pusztai found that the *process* of genetic engineering introduced fundamental changes to the genetics of the potato, to the extent that elements *other* than the natural form of lectin caused test rats to develop a number of health problems, briefly described in Part 1.

Pusztai knew that Europe, being pushed aggressively by pro-transgenics scientists, was rapidly moving towards approving transgenic crops and foods, and that it would take 1–2 years for his results to be published through the peer-review process. He therefore took his results public, a common practice in science (Woloshin and Schwartz, 2002; Bressler et al., 2004), especially with respect to health and medical issues. Pusztai was subsequently dismissed from his post at the Rowett Institute, his large research team disbanded, he was gagged with lawsuit threats, and the research project terminated. Despite formidable resistance and attacks from Britain's main scientific body, the Royal Society (Smith, 2003), his work was published in the medical journal *The Lancet* (Ewen and Pusztai, 1999). According to one molecular biologist: '[t]he Pusztai study is the best designed and carefully controlled study of its kind. Compared to industry studies, it is leagues apart' (Antoniou in Smith, 2007). If Pusztai's results had been suppressed, as was attempted, the transgenic lectin potato would very likely be on the market today.

The Pusztai and Chapela affairs are strong messages for young faculty who wish to develop their careers and research areas – the message is: 'don't challenge the transgenics paradigm if you want tenure'. As Ignacio Chapela is quoted saying, referring to his near denial of tenure experience: 'They have made an example of me. Other scientists see this and decide that maybe they should go back to studying the bristles on the back of a bug' (Ross, 2004).

Editorial bias in peer-review journals against dissenting scientists on the transgenics issue, combined with positive bias for transgenics promoters, is an issue. One study showed that nearly eight out of 10 scholars surveyed perceived bias in the peer-review publication process in favor of scholars who publish material which is positive to the current paradigm and 'normal science' and against recognizing scholars publishing on unorthodox subjects, and that the prestige of the submitter and his/her institution is correlated with passing peer review (Sigelman and Whicker, 1987). Three examples illustrate this pattern in transgenics.

The Chapela Affair: Pressure to Retract a Peer-reviewed Paper Unfavorable to Transgenics

Ignacio Chapela, professor at the University of California Berkeley, tested native corn being grown in indigenous areas of Oaxaca in Mexico and found genetic contamination by transgenes from exported US corn, a highly significant finding that has never been disputed. A second finding in the paper, published in the journal *Nature*, that transgenic DNA is unstable and that fragmentation occurs during the transformation process, was the source of controversy.

On the day the Quist and Chapela (2001) paper was published, emails attacking him and his research started showing up on AgBioWorld, an Internet forum popular with biotechnology scientists. AgBioWorld was associated with the Competitive Enterprise Institute, an industry-funded body 'notorious for its extreme pro-corporate agenda' (GM Watch, 2002a; Matthews, 2003a). The emails accused Chapela of being an 'activist first' and a 'scientist second', that he colluded in attacks on 'biotechnology, free trade, intellectual property rights', and participated in other 'politically motivated agenda items'. They insinuated that Chapela had actually designed his research in collusion with 'fear-mongering activists' and asked how much money Chapela was getting in expenses from the 'anti-biotech industry'. Later, the vice-president of BIO, the Biotechnology Industry Organization, is quoted as saying that the authors' (Chapela and co-author Quist) 'commitment was not to data and science but to a religious commitment to an [anti-biotechnology] dogma' (Matthews, 2003b).

There have been reports in the media that the attacks on Chapela on Internet biotech forums were part of the 'viral marketing strategy' of a specific biotechnology company (Quist and Chapela, 2001), and that these attacks came from 'phantom scientists' – phony personages created by the viral strategists – whose emails were shown to have originated on the servers of the biotechnology company's PR group in the US (Littek, *n.d.*; Monbiot, 2002a, 2002b; Ross, 2004).

After the attacks were posted on AgBioWorld, negative articles began appearing in the press with headlines such as 'Doubts over Mexican GM maize report' (Kirby, 2002). This, plus a massive email campaign to the editor of *Nature*, galvanized support for pressuring *Nature* to retract Chapela's paper. *Nature* appointed a committee to examine possible retraction. The paper's main finding that transgenes were found in native Mexican corn was upheld by the committee. However, the second conclusion of the Chapela paper, that fragmentation and subsequent 'jumping' of transgenic DNA occurs, was not accepted. Nevertheless, despite two of three referees failing to find sufficient reason to retract the paper, *Nature* published a statement that there was 'insufficient evidence to justify the original publication' (Dalton, 2008) (not a retraction). With this decision, 'the biotechnology industry won a major public relations victory', according to one media source (Philipkoski, 2002). BBC News criticized *Nature*'s editor for going against the majority decision of the committees (GM Watch, 2002b). A well-balanced journalistic review of the retraction controversy exists by Salah (2002).

One major point stands out on the Chapela affair after five years: the fragmentation and subsequent movement of transgenic DNA in plants, as posited in the Chapela paper, has become the focus of research, as described in works cited in Part 1 of this paper. The idea that DNA fragmentation and migration to other parts of the genome is 'unprecedented', 'revolutionary', 'totally ludicrous', and 'more mysticism than science' (Sallah, 2002), as described by Chapela's detractors during the controversy, is looking much less likely.

A November 2008 article in *Nature* reports that research to be published in the journal *Molecular Ecology* has replicated Chapela's finding of transgene contamination of native Mexican maize but does not mention DNA fragmentation and migration (Dalton, 2008).

The Wormy Corn Affair: Refusal of a Peer-reviewed Journal to Retract a Discredited Pro-transgenics Paper

In 2003, the *British Food Journal* (BFJ) published a paper by a Canadian research team (Powell et al., 2003) which reported that consumers were 50% more likely to choose transgenic sweet corn than non-transgenic from bins at a farmers market. The paper won the journal's 2004 award for excellence. However, a book (Laidlaw, 2003) on food by a *Toronto Star* journalist showed photos of the corn bins in the study with a sign on the non-transgenic corn saying 'Would you eat wormy corn?' and one on the transgenic corn saying 'Here's what went in producing quality sweet corn', with each sign showing the number of times the corn was sprayed with pesticide (non-transgenic corn much higher). These signs were not reported in the BFJ paper.

A furor developed in which accusations of fraud from detractors and libel and defamation from the one or more of the paper's authors were exchanged. The editor of the BFJ has refused to either retract the paper or the award for excellence or publish any more discussion on the issue. Evidence supporting the contention that the signs were posted during a substantial part, if not all, of the data collection period (several months) has been reported in a letter to the BFJ (Cummings et al., 2008), calling for the paper's retraction, signed by an international roster of 40 scientists. The letter states that the BFJ paper 'is highly misleading, if not a flagrant fraud'.

The Ermakova Affair: Allegations of Unfair Treatment of a Dissenting Scientist by the Editors and Authors of Nature Biotechnology

Irina Ermakova, a physiologist with the Russian Academy of Sciences, has reported significant health problems in rats fed transgenic soy in several experiments, briefly described in Part 1 of this paper. Ermakova has reported her results at conferences but has not published in the peer-reviewed literature (Marshall, 2007).

The widespread reporting of Ermakova's findings prompted a piece in *Nature Biotechnology* (Marshall, 2007) critiquing her experimental protocols. The published critique has elicited allegations of bias on the part of the journal *Nature Biotechnology* and that Ermakova's critics in the article were 'grossly unfair'. According to Ermakova (GeneWatch, 2007), she was invited by *Nature Biotechnology* to answer a set of questions about her research methods and results. She was sent what turned out to be a dummy copy of the article which listed her as author. She was never told the names of the four British and American men, all well-known scientists in transgenics, who turned out to be authors of the critical piece, and she was never shown their comments. Most of Ermakova's references were removed and replaced with citations chosen by the four authors. According to Ermakova, the authors criticized her lack of data but never gave her an opportunity to provide the needed data. *Nature Biotechnology* received a number of letters protesting the article and published some of them in the December 2007 issue of *Nature Biotechnology* (2007), along with a piece by the editor, which stated 'a more thorough editorial effort should be undertaken to ensure that authors whose work is being commented upon have sufficient opportunity to respond to criticisms'.

A glaring fact overshadows and highlights the entire Ermakova affair: that, as of June 2008, virtually no research had been done other than hers which carries out long-term animal feeding comparisons of transgenic vs. non-transgenic foods in which critically important parameters such as reproductive health are closely examined (Domingo, 2007). This fact, in this author's opinion, greatly reduces the ability of the *Nature Biotechnology* critique to delegitimize Ermakova's research and highlights the issue itself and the need for properly funded, designed, and executed research that replicates hers. Soy is the most common and voluminous of the transgenic foods in the human diet, in terms of proteins, which are the critical entity (as distinct from fats or sugars).

Monopolization of Expert Scientific Bodies on Transgenics

The one-sided pro-transgenics view is endemic in elite scientific institutions like the National Academy of Sciences (NAS). The NAS's 2004 book *Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects* (National Academy of Sciences, 2004) clearly shows a pro-transgenics bias. A central theme in the book is the transgenics industry's long-standing and oft-repeated claim, despite the overwhelming evidence to the contrary as described in Part 1 of this paper, that 'genetic engineering is part of a continuum of manipulation of plant genetics that starts with traditional cross[-pollination] and selection of plants and animals'. To attempt to overcome this gap, the authors of the NAS book have a chapter entitled (italics this author's) 'The adverse impact of *foods* on human health'.

Another chapter in the book, 'Unintended effects from breeding', follows the same argument of putting transgenics on a continuum with traditional plant breeding, discussing the relatively rare cases where traditional breeding gives rise to foods with allergens or nutritional problems and not discussing the fact (Zolla et al., 2008) that potential allergen-generating proteomic changes in transgenic foods are much more common than in foods from traditional breeding methods.

The book does discuss the unintended effects of transgenics, but by putting these effects in the same class as unintended effects of traditional plant breeding, it gives the impression of neutralizing those negative effects. The press release from the National Academies Press on the book states: 'Genetic engineering… poses no unique health risks that cannot also arise from conventional breeding and other genetic alteration methods'. No mention is made in the press release that such health risks occur rarely in conventional breeding and appear to be common in transgenics.

A 2008 issue of the journal *Science* features a cover story on genetically engineered crops and their worldwide spread. In the editorial for that issue, the editor states: 'Genetically modified GM cotton and corn… have been adopted very rapidly in some countries, particularly the United States and Canada, increasing yields and decreasing the use of pesticides and herbicides'. The first assertion is patently false, as no yield increases have been shown by transgenic over non-transgenic crops. A second assertion, that herbicide use has decreased, is highly questionable. The fact that the assertion of a major myth (higher yields), a myth which has been thoroughly debunked in the past 10 years, can be published in the lead editorial of the top US science journal is indicative of the state of affairs of scientific discourse on this issue.

A 2004 report from another expert body, the Pew Initiative on Food and Biotechnology repeats the argument that transgenics is an extension of traditional plant breeding and makes the startlingly hubristic statement that, 'In some ways, genetic engineering is more precise than conventional breeding, because scientists know what genetic material is being introduced and generally understand the functions of the expressed proteins' (Pew Initiative on Food and Biotechnology, 2004). This is in stark contrast to the statement of Latham et al. (2006) in their paper on the mutational consequences of plant transgenics: 'it is clear that plant transformation is rarely, if ever, precise' and that this lack of precision poses a 'significant biosafety risk'. The argument that 'genetic engineering is more precise' is common amongst promoters of transgenic crops, the most recent for this author coming in a conversation with a University of California agricultural extension agent when discussing transgenic corn.

A 2007 report from the same Pew Initiative on Food and Biotechnology (2007) maintains the pro-transgenics view, indicating no change, despite much research since 2004 giving evidence to the contrary. Referring to the roster of pro-transgenics authors of the 2007 report, a former biotechnology specialist for the US EPA, now with the Union of Concerned Scientists states: 'As well as the many industry representatives behind this report, there are also long-familiar GE-promoters… There is no one I recognize who has been seriously critical of any aspects of GE… [T]he report reflects the one-sided input – sometimes to an almost bizarre degree' (GM Watch, 2007c).

Deficient Research Practices

Federal food safety regulatory protocols which allow transgenic food-producing companies to carry out food-safety studies with virtually no oversight have allowed a pattern of poor scientific protocols to become commonplace throughout the food-related industry. The science community has had issues of lack of oversight of the safety and nutrition testing of products by the producing companies, and questions of scientific validity and rigor of industry-sponsored research have arisen repeatedly. In one study of 206 articles reporting nutritional evaluations of industry products, 0% of the industry-sponsored articles reported negative results, while 37% of reports from independently-funded studies showed negative results (Lesser et al., 2007). Such startling findings have been confirmed in other studies (Bekelman et al., 2003), and have completely changed this author's reading and interpretation of scientific reports.

This pattern of lack of rigor and of data manipulation appears to have become endemic in the safety testing of transgenic foods by producing companies. Allegations of fraud in the safety testing of transgenic crops on the part of a biotechnology company have recently emerged in Europe (Ho et al., 2007; Seralini et al., 2007). Monsanto's MON863 corn was approved for use in the EU in 2005 after a controversial approval process. Groups opposing its release attempted to obtain Monsanto's safety-testing data, prompted by independent tests that showed problems with rats fed MON863. After a court injunction forced Monsanto to release the data, French researchers analyzed it and found statistically significant problems with the test-animals' health, which had not been reported by Monsanto.

In a 2007 press conference, the researchers stated that 'there are significant deficits in the statistic[al] evaluation of the Monsanto report', and that 'these revelations are profoundly disturbing from a health point of view. They are certainly sufficient to require new and more carefully conducted feeding studies and an immediate ban from human or animal consumption of GM corn MON 863 and all its hybrids' (Seralini et al., 2007), MON863 lines of corn are currently grown in the US, the EU, Australia, Canada, China, Japan, Mexico, and the Philippines. France is currently moving toward a freeze on transgenic crops (Jakubyszyn and Kempf, 2007) and the EU is moving toward a ban on transgenic corn (Kanter, 2007).

Several questionable practices are reported to be common in industry-conducted animal feeding tests of transgenic foods (Pryme and Lembcke, 2003; Bardocz and Pusztai, 2006). Most feeding studies are done without using the whole transgenic food – instead, isolations of the transgenic protein are fed to the animals. This would exclude rogue proteins produced by mutations, a known problem in transgenics, discussed in Part 1 of this paper. A similar practice is to use surrogate proteins, produced by transgenic bacteria, not by the transgenic plant. This practice gave rise to the difficult-to-detect glycosylation problem and subsequent allergenicity in the Australian pea research discussed in Part 1, as bacteria do not glycosylate proteins as do plants. Other common practices are: shortening the duration that test animals are fed to the minimum time possible, thus minimizing the chance of showing long-term effects; the exclusive use of adult animals, which are significantly less prone to show problems in feeding trials than young or infant animals; the use of animals with wide variation in weight, which reduces the significance of treatment effects; diluting the transgenic food with other foods; and using irrelevant control groups that make comparisons to treatment groups difficult (Pryme and Lembcke, 2003; Smith, 2007).

Political Manipulation of Government Science

Political manipulation of federal government science and scientists has become a serious problem (Vergano, 2007), and has been an important factor in the development of the current dysfunctional transgenic foods situation. It is disturbing to this scientist–author that US science's leadership bodies, such as the National Academy of Sciences or the American Association for the Advancement of Science (AAAS), have not brought this issue to the forefront of mainstream media and college science curricula.

A 2006 survey of a thousand FDA scientists that was carried out by the Union of Concerned Scientists (2006) on the state of scientific practice within the organization showed that more than half of the scientists, 61%, knew of cases in which political appointees 'inappropriately interjected themselves into FDA determinations or actions'. The same percentage knew of cases 'where commercial interests have inappropriately induced or attempted to induce the reversal, withdrawal, or modification of FDA determinations or actions'. To quote one scientist surveyed: 'Scientific discourse is strongly discouraged when it may jeopardize an approval.… Whenever safety or efficacy concerns are raised on scientific grounds… those concerns are not taken seriously'. As related in Part 1 of this paper, FDA scientists' warnings about transgenic foods were systematically ignored by politically appointed administrators.

The Information Environment and Transgenics

Media reporting on transgenics is often biased. It has been shown that agricultural journalists tend to side overwhelmingly with pro-transgenics university scientists on biotechnology issues and see them as 'trustworthy, unbiased, and fair', while dissenters are seen as 'untrustworthy, completely biased, and unfair in communicating agricultural biotechnology issues' (Wingenbach and Rutherford, 2005). Biotechnology industry reports which are widely quoted in agricultural media often contain no citations, while well-cited reports from anti-transgenics groups are routinely rejected (Leahy, 2007). If mainstream US news media depend on agricultural media for their occasional pieces on transgenic foods, this can be seen as a reason why Americans have been shown to be 'seemingly untroubled by a technology that causes Europeans so many difficulties' (Gaskell et al., 1999).

Bias, sometimes subtle, exists in the dissemination of information on transgenics to the public. A common theme in articles and information on transgenic foods is that 'consumers just need to be educated about the benefits of GM foods' (James, 2004; Leonard, 2007; Wheeler, 2008). In this doctrine, laypeople are essentially given the choice of being ignorant (anti-transgenics) or enlightened (pro-transgenics).

'Technological utopianism' via biotechnology is a term used by European observers to describe the tone of advisory documents submitted to the European Union by consultants of the biotechnology industry during the approval process for transgenic crops (Bioscience Resource Project, 2007).

Another important component of the pro-transgenics sector's manipulation of the information environment is a not-so-subtle targeting of the general public's predisposition to guilt. The message that 'biotechnology is needed to feed a hungry world' has come to the forefront as a strategy in the promotion of transgenics, and associated guilt is one of the tactics used by transgenics industry spokespeople: 'The real issue in this world is not biotechnology, the real issue is starvation', one university spokesperson is quoted as saying (Knudson and Lee, 2004). (I have heard the same spokesperson make the statement more than once.) The headline in an issue of Monsanto's electronic newsletter *The Biotech Advantage* read 'Academics Say Africans Going Hungry Because of Activist Scare Tactics', while a Monsanto-India web page for some time had a link to an article entitled 'Green Killers and Pseudo-Science', referring to opponents of transgenic crops being killers because they would allegedly allow people to die of hunger because of their opposition to transgenic crops (Lopez-Villar et al., 2007). The poster-child project for this PR strategy of the transgenics industry has been the now-discredited 'golden rice', rice genetically engineered to produce vitamin A (BIOTHAI et al., 2001). The golden rice endeavor was labeled by author Michael Pollan as 'The Great Yellow Hype' (2001).

The industry's PR strategy of 'fighting hunger with biotechnology' is encountering problems. Former UN Secretary General Kofi Annan, heading a multilateral alliance addressing Africa's future food security, announced that the group has rejected transgenic crops as a solution in the African war on hunger (Odhiambo, 2007). The same view has appeared, albeit less visibly, in India (Sharma, 2007), where failure of transgenic crops has been common (Menon, 2007).

A study by South African scientists (African Centre for Biosafety, 2007) has called into question the role of transgenics in the development of food security in the face of aggressive promotion by pro-biotechnology forces, including the US's Rockefeller Foundation. The study reports that, despite the extreme complexity and long-term nature of developing drought tolerant crops via transgenics, and that drought tolerant crops are 8–10 years away from implementation, 'GM drought tolerant crops are being used as powerful PR tools by the biotech machinery and strategic philanthropy [organizations] such as the Rockefeller Foundation to promote acceptance of GM crops, expand existing markets and develop new markets'.

The promotion of transgenic crops and foods to farmers and consumers by university extension programs, despite the tag of being 'market driven', goes against market trends. Consumers have overwhelmingly rejected transgenic foods since 1994. The Center for Food Safety, referring to transgenic foods, writes, 'The depth of market rejection is arguably unparalleled by any other consumer product' (Center for Food Safety, 2006).

A Well-established Alternative to Transgenics for Future World Food Production

In April 2008, 57 nations signed a an action plan for future world food production in developing countries, known as the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). The United Nations-sponsored IAASTD was authored by over 400 agricultural scientists and experts and stands to become the reference point around which future agricultural development takes place.

At the heart of the final report (IAASTD, 2008) is the idea that local and regionally derived sustainable and agro-ecological strategies which take into account social impacts should be the basis of future food production; that the hitherto capital intensive, high-environmental impact, technology- and yield-centered approach of Green Revolution agriculture needs changing in developing countries; and significantly, that transgenics and proprietary biotechnologies are not likely to be at the center of this roster of strategies.

The IAASTD report emphasizes agroecological approaches:

> '[S]ystems are needed that enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems. Options include improving nutrient, energy, water and land use efficiency; improving the understanding of soil-plant-water dynamics; increasing farm diversification; supporting agroecological systems, and enhancing biodiversity conservation and use at both field and landscape scales' (IAASTD, 2008).

Interestingly, one of the two biotechnology-industry representatives, Syngenta, who was part of the initial idea of convening a food production strategy agreement for developing countries, exited the IAASTD proceedings in January 2008, when it was clear that their agenda was not to be at the center. The United States, Canada, and Australia did not sign the agreement.

Studies have shown that non-proprietary agro-ecological methods are an effective strategy for future food production in the developing world (Pretty et al., 2006). A recent study reported that organic agricultural methods could provide the basis for world food security (Badgley et al., 2007), and the UN Food and Agriculture Organization in a 2007 report states that, 'organic agriculture can address local and global food security challenges', and it recommends that the United Nations 'consider promoting organic supply systems as a food security strategy' (FAO, 2007).

The author's own work showed that organic crop systems can be more robust than conventional systems under conditions of environmental stress (Lotter et al., 2003), a scenario that is increasing as a result of global climate change. In the study we showed that, in a 21-year farming systems comparison study in Pennsylvania, the organic system out-yielded the conventionally managed crops by up to 100% during drought years, as well as eroding less and capturing more water during torrential rain events.

Such improvements in crop performance under drought stress, had they been achieved by transgenics, would have been the subject of weeks of headlines and TV coverage in mainstream press. Nevertheless, tens of millions of dollars are being invested in the transgenics route to crop drought resistance (Ojanji, 2007).

This author does not believe that future food production should be limited to organic methods as defined by current certification protocols. However, the agro-ecological techniques which are the basis of organic crop production can provide the foundation for world food production. Selected non-organic conventional methods can be used to bolster the agro-ecologically engineered foundation of crop production. For example, moderate amounts of synthetic nitrogen to bolster cover crop-based fertility – carefully timed to reduce leaching into water systems – the use of treated seed, and the selective use of herbicides are such technologies which would enhance the yields and efficiency of agro-ecologically based methods. These methods, which combine organic and conventional techniques, are known as 'integrated', have been well-researched in Europe, and consistently show robust, sustainable results (Holland et al., 1994).

The model proposed here is that agro-ecological engineering is the foundation upon which crop systems should be based, on top of which can be put chemical and biotechnological modalities. Both levels of the pyramid would be 'high tech'. Agro-ecological techniques are often 'hi-tech'. For example, these strategies may make simultaneous use of automated biometeorological monitoring using computer models; careful arthropod pest monitoring; application of viral, bacterial, or fungal biological control agents; management of soil organic matter dynamics to facilitate optimum nutrient release and root environment; soil and plant nutrient status monitoring; weed and non-crop plant community monitoring; and close monitoring of other research-based agro-ecological parameters.

Uphoff (2007) discusses the problem of agro-ecological approaches in agricultural development being overlooked because of the preoccupation with 'genocentric' strategies. He uses the example of the System of Rice Intensification, put in place in a number of developing countries, in which yields have been increased by 30–100% via agro-ecological methods which require little investment and are available to local farmers. Australian agronomists report in India, where debt problems have become epidemic for farmers trying to transition to transgenic cotton, that with integrated pest management and non-transgenic cotton varieties, overall pesticide use can be reduced by 50% and profits increased by 75% (Bhandari, 2007). Other authors have discussed similar agroecology-based productivity increases (Bunch, 2002; Lotter, 2003).

A critical point, however, is that these agro-ecological engineering strategies are predominantly non-proprietary and not patentable. Agro-ecological engineering does not attract private investment, as these techniques do not lend themselves to proprietary ownership and patents, and therefore must be funded by public monies, i.e. federal and state programs. These modalities are also, in most cases, not transferable en masse; they generally must be researched and developed for each crop and each ecosystem, which necessitates a dedicated and widespread research and extension system.

The past 25 years have seen this sector of agricultural research receive a smaller and smaller share of public research monies as university commercialization of research progressed – indeed, only a tiny fraction of the total research monies allocated – while biotechnology-related research at universities has long received the 'lion's share' of federal monies for agriculture (Kaiser, 2000), despite the fact that most of the biotechnologies are proprietary and also garner substantial private investment. The integrated, non-proprietary, ecological engineering-based solutions should form the first line of attack in future world food production strategies, and most public-sourced investment in agricultural research should go here.

Without a robust research and extension base for non-proprietary, ecologically based agricultural systems, US farmers may be increasingly unable to compete in the global market in the future if competing farmers in other countries have efficacious, low-cost, non-proprietary methods being developed by their public institutions. Many of these ecologically and biologically based methods have low implementation costs in addition to being royalty free.

Biotechnology will still have its place in the development of food production. For example, an important biotechnology alternative to transgenics is marker-assisted selection, in which non-invasive biotechnological methods are used to mark desirable genes for efficient selection in traditional breeding programs. Cultivars of rice (Sasaki, 2006) and wheat (BBC News, 2006) have been developed via marker-assisted selection.

Conclusion

The transgenic foods debacle is a classic case for the need to incorporate elements of the precautionary principle (Raffensberger and Tickner, 1999) into science policy, as well as to rescue elements of scientific independence and integrity from the damage done by the restructuring of university science towards the academic capitalism model of the past 25 years. Had either the precautionary principle or protocols for true scientific independence and integrity been in place during the approval process for transgenic crops, even minimally, the emerging conflict between pro-transgenic foods forces and those opposing them would have taken place before the heavy investment in the development of the industry.

The decision to oppose transgenic food in its current form should not automatically imply opposition to all transgenics. Parsing transgenic foods from the larger transgenics sector and accepting that it may be a failed enterprise gives the majority of biotechnology-invested and transgenics-invested scientists an 'out' from the conflict, as most transgenics scientists, in this author's view, work on non-food products and species for industrial or pharmaceutical ends.

It appears that the science community has two paths it can take on transgenic foods. One is to continue its entrenchment and denial of the problem, the other is to parse crop transgenics from the larger transgenics issue so that it can be the subject of a market roll-back without jeopardizing the rest of the industry. The likely result of denial of the problem will be that the consumer, and thus the market system, will reject transgenic foods. Consumers, with sufficient market choice and with nagging questions about the safety of transgenic foods (and all they need are doubts) will likely exercise their power and simply move to the ever-growing organics sector, or to known non-transgenic foods. In an economy that prides itself on market choices, those non-transgenic products are very likely to become increasingly available at competitive prices.

A widespread consumer movement to non-transgenics and organics would lead to an unsustainable situation for investors in and developers, producers, and marketers of transgenic foods, a scenario that already appears to be in its beginning stages, as discussed earlier. The benefits of transgenic foods to the consumer have never been clear to those consumers, and unless the biotechnology industry develops a transgenic food that delivers some major benefit which traditional foods lack, consumers are unlikely to be convinced to buy them. Such a breakthrough class of products would likely fall into the single-compound (as discussed in Part 1) pharmaceutical/nutraceutical category anyway, an area of potential growth for transgenics.

Cost-cutting breakthroughs in food production via transgenics are unlikely to mean very much to consumers in a country where only 7–8% of consumer income goes to food. Conversely, high prices are paid for gourmet foods and wines, a market sector which prides itself on food purity and tradition, and which was at the leading edge of the first US opposition to transgenic foods, and remains steadfastly opposed to them. After transgenic foods fail in the market, its disendorsement by the scientific community will then likely follow, at the risk of the science community having lost much credibility, however.

What appears to be a significant trend in the crop seed development industry made itself clear to this author on a recent vegetable crops class field trip that I led to the headquarters of the largest vegetable seed company in the world, which is owned by the largest agricultural biotechnology company in the world. When asked by the students about the development of genetically engineered crops, a senior scientist at the company stated that there is very little genetic engineering going on currently, and that '90% of our biotechnology work is on biomarkers' (otherwise known as marker-assisted selection, a non-transgenic technology for rapid identification and development of favorable crop traits). Thus it appears that, while the industry continues to defend transgenics in public, behind the scenes the investment in transgenics is on the decline.

The entrenchment of the scientific community with respect to transgenic foods could lead not only to consumer rejection of transgenic foods but also to the possibility of the public rejecting all biotechnology and a good part of science as well – tantamount to 'throwing the baby out with the bath water'. This scenario risks the development of widespread public mistrust of science, especially amongst the young. On the other hand, the science community can cut its losses, open up to the idea that food crop transgenics is deeply flawed and needs to be subject to a market roll-back and comprehensive re-analysis, and then give the public some transgenic products that it really needs and can trust – like effective pharmaceuticals produced in enough quantity to be available to the average health-care consumer. This would restore public trust in science and may re-invigorate science itself.

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